Federal Communications Commission Office of Engineering and Technology Staff
Report on Demonstrations of Globalstar, Inc.'s Proposed Terrestrial Low-Power Service
March 6, 9-10, 2015
IB Docket No. 13-213
March 27, 2015

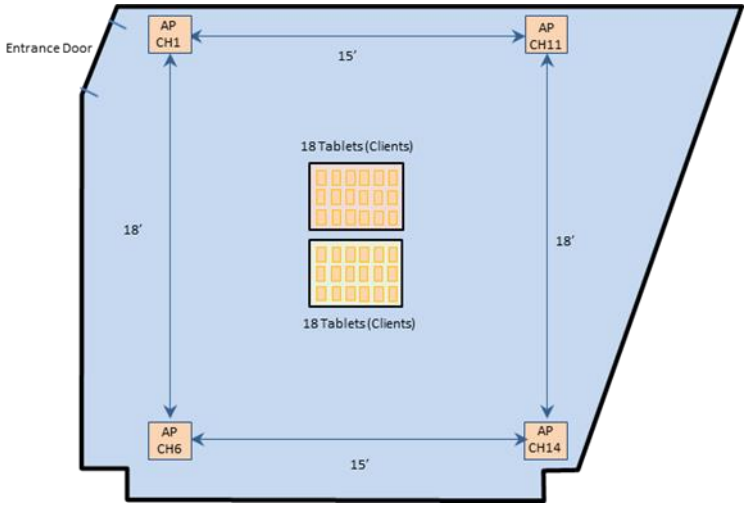
This is a report of the observations of FCC staff of the demonstrations of Globalstar, Inc.'s proposed terrestrial low power service (TLPS) that would operate on channel 14 (2473-2495 MHz) of the IEEE 802.11 standard. This report documents the environment set-up, equipment used, transmissions parameters (EIRP, data rate), and Wi-Fi channels operated during the demonstrations. It does not contain any staff anaylses of those demonstrations.

On March 6, 9-10, 2015, Bluetooth SIG, Inc., CableLabs, Globalstar, Inc., National Cable Television Association (NCTA), and the Wi-Fi Alliance (WFA) were participants in demonstrations at the FCC's Technology Experience Center to observe Globalstar's proposed TLPS operations on channel 14 with existing Wi-Fi devices and Bluetooth classic (BT) and Bluetooth low-energy (BLE) devices operating in the 2400-2483.5 MHz band. Starkey Laboratories, Inc. (Starkey Labs) and Cambridge Silicon Radio (CSR) conducted demonstrations on BLE devices on behalf of Bluetooth SIG; AT4 wireless, Roberson and Associates, LLC, and Jarvinian conducted demonstrations on BT, BLE, and Wi-Fi devices on behalf of Globalstar; and CableLabs conducted demonstrations on Wi-Fi devices on behalf of NCTA and the Wi-Fi Alliance. The Wireless Internet Service Providers Association (WISPA) participated in the planning of the demonstrations, and indicated that they were satisfied with CableLabs' planned demonstrations. The participating parties are expected to submit their own results and analyses into the record.

AT4 wireless', Roberson and Associates', and Jarvinian's Demonstrations of TLPS Impact on Bluetooth Classic and Bluetooth Low-Energy Devices

On March 6, 2015, AT4 wireless, Roberson and Associates, and Jarvinian conducted demonstrations on Bluetooth Classic (BT) and Bluetooth low-energy (BLE) devices. The demonstrations were conducted with four access point (AP)-client pairs operating on Wi-Fi channels 1 (2401-2423 MHz), 6 (2426-2448 MHz), 11 (2451-2473 MHz), and channel 14 (2473-2495 MHz) (*i.e.*, the TLPS channel). The APs were set to operate at -8 dB transmit power setting equivalent to 20 dBm (100 mW) conducted power, 23 dBm (200 mW) equivalent isotropically radiated power (EIRP) including antenna gain based on manufacturer data sheet. The APs and client devices were positioned as shown in the figure below.

Floor Plan for Demonstrations of Globalstar TLPS at the FCC's Technology Experience Center

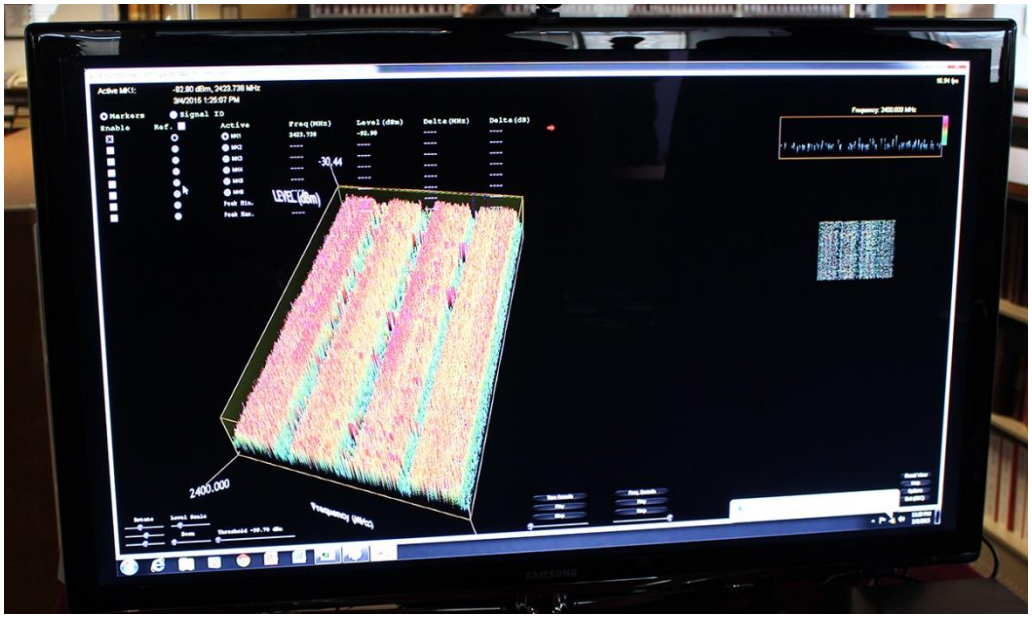


Notes:

- All dimensions are approximate; drawing is not to scale
- Access Points (APs): Ruckus Wireless Model 7982, 3x3 MIMO
- APs were located on posts approx. 8 feet above the floor
- APs transmitter power were set to a minimum 23 dBm EIRP
- APs have beam forming mode

Each AP was streaming video to one tablet, with AP-client pairs operating on Wi-Fi channels 1, 6, 11, and 14. The Wi-Fi downlink (AP to client) traffic generated between each AP-client pair consisted of emulated high-definition (HD) video streaming at a nominal rate of 3.75 Mbps, using User Datagram Protocol over Internet Protocol for the wireless link.

Channel 1 AP



Display of Signals Generated on Wi-Fi Channels 1, 6, 11, and 14

BT and BLE Demonstrations:

1. - Speaker: Sony SRS-X5 Personal Audio System portable Bluetooth speaker

BT Speaker

- Computer: Microsoft Surface Pro 3 tablet with i7 processor, 8 GB RAM running Windows 8.1
- Maximum BT EIRP: 20 dBm (100 mW)
- Music Player: Xbox Music player pre-installed on Surface Pro 3
- Music: Mozart Serenade in G, “Eine kleine Nachtmusic”, Allegro movement - 145 kbps mp3

The BT speaker was connected via a BT link to the tablet computer with a music player that was located near the center of the room. The user experience demonstrated was the sound quality of the music played through the speaker as the speaker was located at various positions in the room and the Wi-Fi and TLPS APs were operating.

2. - BLE Heart Rate Monitor: Adidas Fit Smart Band - Model: M33705
   - Maximum BLE EIRP: 10 dBm (10 mW)
   - Smart Phone: Motorola Droid Mini running Android 4.4.4, 2 GB RAM, 16 GB ROM
   - Heart Rate Monitor Application: Bluetooth Heart Rate Monitor ver. 1.61 (published by Jeremiah Huston on Google Play Store) - Heart Rate Source: Michael Needham of Roberson and Associates

The wrist-worn heart rate monitor was connected via a BLE link to the smart phone running a heart rate monitor application. The smart phone was located on a shelf along one side of the room between the channel 6 and channel 14 APs, where it could be observed by all of the parties. The user experience demonstrated was the constant reading of heart rate as displayed on the smart phone as the user wearing the heart rate monitor moved throughout the room and the Wi-Fi and TLPS APs were operating.

3. - Wireless Mouse: Logitech - M557 Bluetooth Mouse - Model: 910-003971
   - Maximum BT EIRP: expected maximum EIRP of 4 dBm (2.5 mW) (Class 2 device)
   - Laptop Computer: HP Envy with 2.4 GHz i7 processor, 16 GB RAM running Windows 8.1
   - Web Browser: Mozilla Firefox ver. 35.0.1

BT Mouse and BLE Mouse

A wireless mouse was connected via a BT link to a laptop computer running a web browser. The laptop was located near the center of the room and positioned so the screen could be observed by all of the parties, while the mouse was located a couple of feet away. The user experience demonstrated was the operation of the mouse in opening and closing a browser window, scrolling through the window, and clicking on links while the Wi-Fi and TLPS APs were operating.

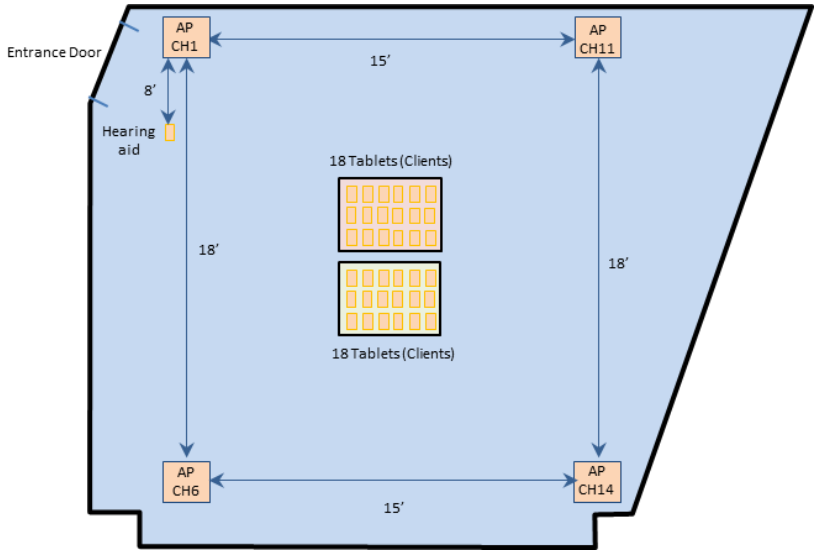
4. - BLE Wireless Mouse: HP - Wireless Bluetooth Smart Laser Mouse - Model: z8000
   - Maximum BLE EIRP: 10 dBm (10 mW)
   - Laptop Computer: HP Envy with 2.4 GHz i7 processor, 16 GB RAM running Windows 8.1
   - Web Browser: Mozilla Firefox ver. 35.0.1

Demonstrations identical to that described in item 3 above were conducted.

Starkey Labs' Demonstrations of TLPS Impact on Bluetooth Low-Energy Devices

On March 6, 2015, Starkey Labs conducted demonstrations to measure the TLPS impact on BLE transmissions to a BLE hearing aid operating on BLE data channels 0-10 (2404-2424 MHz) and 11-36 (2428-2478 MHz). The accsess points (APs) were set to operate at -8 dB transmit power setting equivalent to 20 dBm (100 mW) conducted power, 23 dBm (200 mW) equivalent isotropically radiated power (EIRP) including antenna gain based on manufacturer data sheet, and were positioned as shown in the figure below. The BLE hearing aid was located on a table approximately 8 feet from the channel 1 AP.

Floor Plan for Demonstrations of Globalstar TLPS at the FCC's Technology Experience Center



Notes:

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- Access Points (APs): Ruckus Wireless Model 7982, 3x3 MIMO
- APs were located on posts approx. 8 feet above the floor
- APs transmitter power were set to a minimum 23 dBm EIRP
- APs have beam forming mode

Each AP was streaming video to one tablet, with AP-client pairs operating on Wi-Fi channels 1 (2401-2423 MHz), 6 (2426-2448 MHz), 11 (2451-2473 MHz), and TLPS channel 14 (2473-2495 MHz). The Wi-Fi downlink (AP to client) traffic generated between each AP-client pair consisted of emulated high-definition (HD) video streaming at a nominal rate of 3.75 Mbps, using User Datagram Protocol over Internet Protocol for the wireless link.

As pictured below, the following equipment was used to establish the BLE pairings:

- Apple iPhone 6 (FCC ID: BCG-E2B16A) EIRP: 10 dBm (10 mW)
- Apple iPhone 6 plus (FCC ID: BCG-E2817A) EIRP: 10 dBm (10 mW)
- Starkey Laboratories, Inc. Two-way BLE Hearing Aid (FCC ID: EOA-24HALOXF13)
- Hearing aid maximum EIRP: -7 dBm (0.20 mW)
- BLE Hearing Aid antenna gain: -7 dBi

For the BLE traffic, audio streams using the Apple music player were transmitted from either an iPhone 6 or iPhone 6 plus to the BLE hearing aid located on a table approximately 16 feet from the iPhone to simulate a wireless microphone/wireless auditory assistance device in an auditorium. During the audio stream transmissions, three AP-client pairs were operated simultaneously on Wi-Fi channels 1, 6, and 11

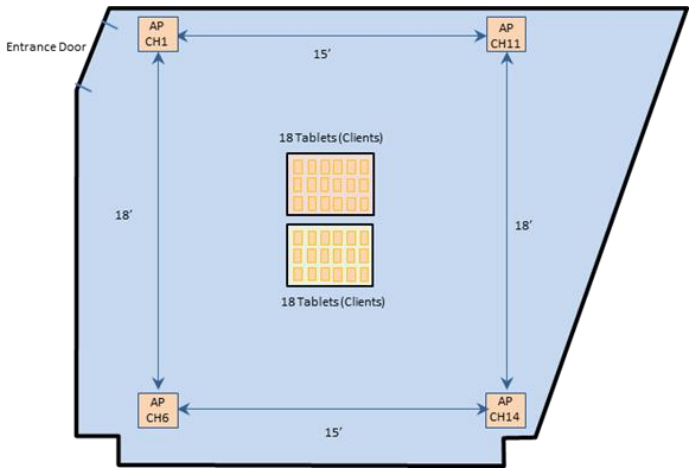
to observe the baseline performance, and then four AP-client pairs were operated simultaneously on Wi-Fi channels 1, 6, and 11, and TLPS channel 14. The audio received by the BLE hearing aid located on the table was recorded and the packet error rate of the received signal measured. To obtain a user's experience, demonstrations were conducted with the hearing aid worn by a user and the iPhone placed in the user's pants pocket while the user was walking around the room.

iPhone 6 and Bluetooth Low Energy Hearing Aids

CSR's Demonstrations of TLPS Impact on Bluetooth Low-Energy Devices

On March 6, 2015, Cambridge Silicon Radio (CSR) conducted demonstrations of the TLPS impact on BLE advertising channels 37 (2401-2403 MHz), 38 (2425-2427 MHz), and 39 (2479-2481 MHz) used as beacon channels to activate CSRmesh® lighting boards (BLE mesh devices). The APs were set to operate at -8 dB transmit power setting equivalent to 20 dBm (100 mW) conducted power, 23 dBm (200 mW) equivalent isotropically radiated power (EIRP) including antenna gain based on manufacturer data sheet, and were positioned as shown in the figure below.

Floor Plan for Demonstrations of Globalstar TLPS at the FCC's Technology Experience Center



Notes:

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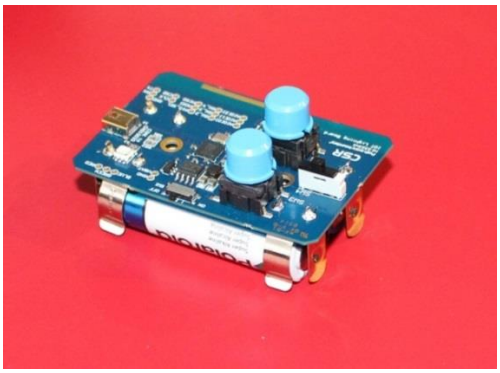
- APs were located on posts approx. 8 feet above the floor
- APs transmitter power were set to a minimum 23 dBm EIRP
- APs have beam forming mode

Each AP was streaming video to one tablet, with AP-client pairs operating on Wi-Fi channels 1 (2401-2423 MHz), 6 (2426-2448 MHz), and 11 (2451-2473 MHz), and TLPS channel 14 (2473-2495 MHz). The Wi-Fi downlink (AP to client) traffic generated between each AP-client pair consisted of emulated high-definition (HD) video streaming at a nominal rate of 3.75 Mbps, using User Datagram Protocol over Internet Protocol for the wireless link. During the demonstrations, one of the APs was operated on Wi-Fi channel 3 (2411-2433 MHz).

The following devices were used to establish the BLE pairings: Asus Nexus 1.02 Android Device, CSRmesh lighting board: DK-CSR1010-10185-1A, EIRP: 0 dBm (1 mW).



CSRmesh lighting board

Five CSRmesh devices were positioned throughout the room in the following locations:

- Approximately 7 feet from the channel 1 AP
- Approximately 7 feet from the channel 6 AP
- Approximately 7 feet from the channel 11 AP
- Approximately 4 feet from the channel 14 AP
- Near the center of the room, approximately 18 feet from the channel 14 AP

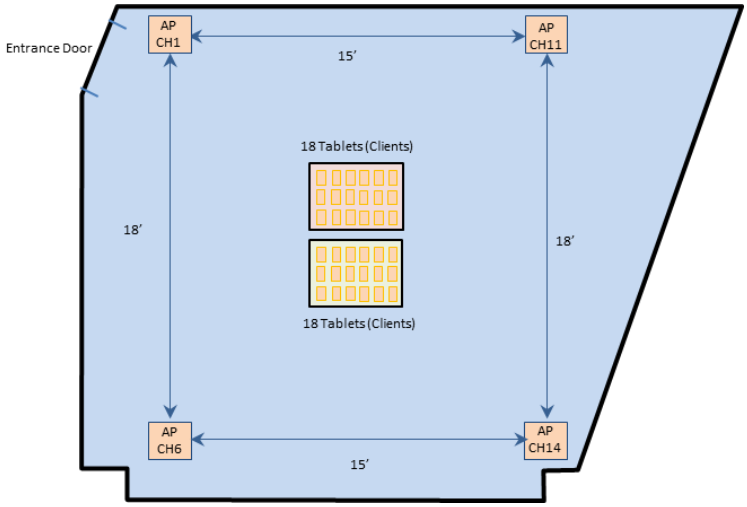
To activate the CSRmesh devices, a BLE signal was transmitted from an Asus Nexus 1.02 Android device. One CSRmesh device would receive and retransmit the signal information for reception by all of the remaining CSRmesh devices. The performance of the CSRmesh devices was observed when the APs were operating with the following Wi-Fi and TLPS channel combinations:

- 1, 6, 11
- 1, 6, 11, 14
- 3, 11, 14
- 3, 11

AT4 wireless', Roberson and Associates', and Jarvinian's Demonstrations of TLPS Impact on Wi-Fi Devices

On March 9, 2015, AT4 wireless, Roberson and Associates, and Jarvinian conducted demonstrations of Globastar's TLPS using Android 4.4.4 Wi-Fi client devices. Four Wi-Fi clients per access point (AP) (*i.e.*, per channel) were connected when Wi-Fi channels 1, 6, and 11 were operating; 3 Wi-Fi clients per AP were connected when Wi-Fi channels 1, 6, 11, and TLPS channel 14 were operating. The Wi-Fi clients were located near the center of the room, approximately 11 feet from the channel 14 AP and equidistant to all of the APs. During the demonstrations, 137 kbyte packets were generated continuously from the APs to the client devices (downlinks). The APs were set to operate at -8 dB transmit power setting equivalent to 20 dBm (100 mW) conducted power, 23 dBm (200 mW) equivalent isotropically radiated power (EIRP) including antenna gain based on manufacturer data sheet, and were located as shown in the figure below.

Floor Plan for Demonstrations of Globalstar TLPS at the FCC's Technology Experience Center



Notes:

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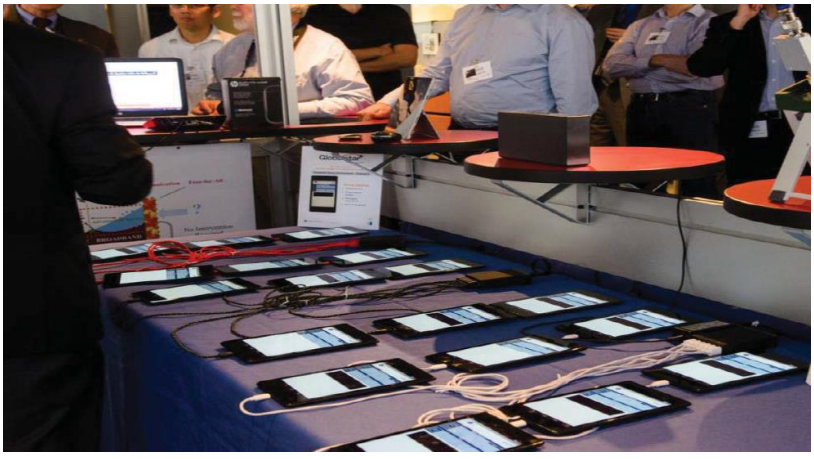
- Access Points (APs): Ruckus Wireless Model 7982, 3x3 MIMO
- APs were located on posts approx. 8 feet above the floor
- APs transmitter power were set at a minimum of 23 dBm EIRP
- APs have beam forming mode



Wi-Fi Clients (Android 4.4.4)

The aggregated downlink data throughput per channel was measured with 4 Wi-Fi client connections per AP (3 APs operating on 3 channels) for the following channel combinations:

- Ch. 1 only
- Ch. 6 only
- Ch. 11 only
- Chs. 1, 6, and 11 simultaneously

The aggregated downlink data throughput per channel was measured with 3 Wi-Fi client connections per AP (4 APs operating on 4 channels) for the following channel combinations:

- Ch. 1 only
- Ch. 6 only
- Ch. 11 only
- Ch. 14 only
- Chs. 1, 6, and 11 simultaneously
- Chs. 1, 6, 11, and 14 simultaneously

The aggregated downlink data throughput per channel was measured with 3 Wi-Fi client connections per AP (4 APs operating on 3 channels) for the following channel combinations:

- Ch. 1 only
- Ch. 6 only
- Ch. 11 only
- Ch. 6 only (2^{nd} AP channel)
- Chs. 1, 6, and 11 simultaneously
- Chs. 1, 6, 11, and 2nd AP Ch. 6 simultaneously

The aggregated downlink data throughput per channel was measured with 3 Wi-Fi client connections per AP (4 APs operating on 2 channels) for the following channel combinations:

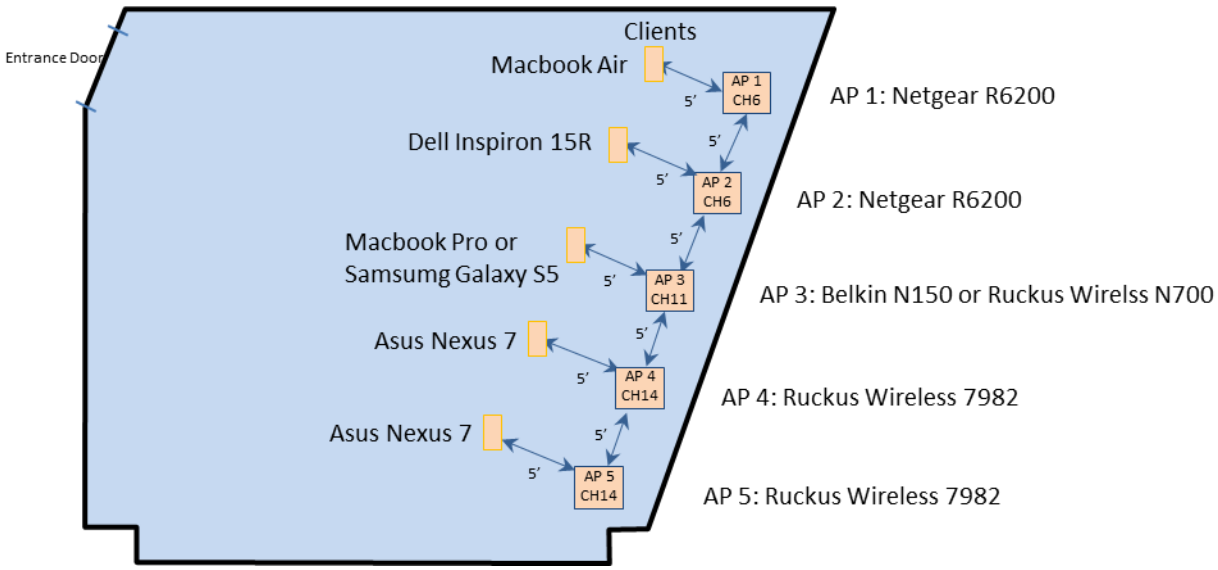
- Ch. 11 only
- Chs. 1, 14, 2^{nd} AP Ch. 14, and 3^{rd} AP Ch. 14 simultaneously

The network aggregated downlink data throughput for the following channel combinations was also measured:

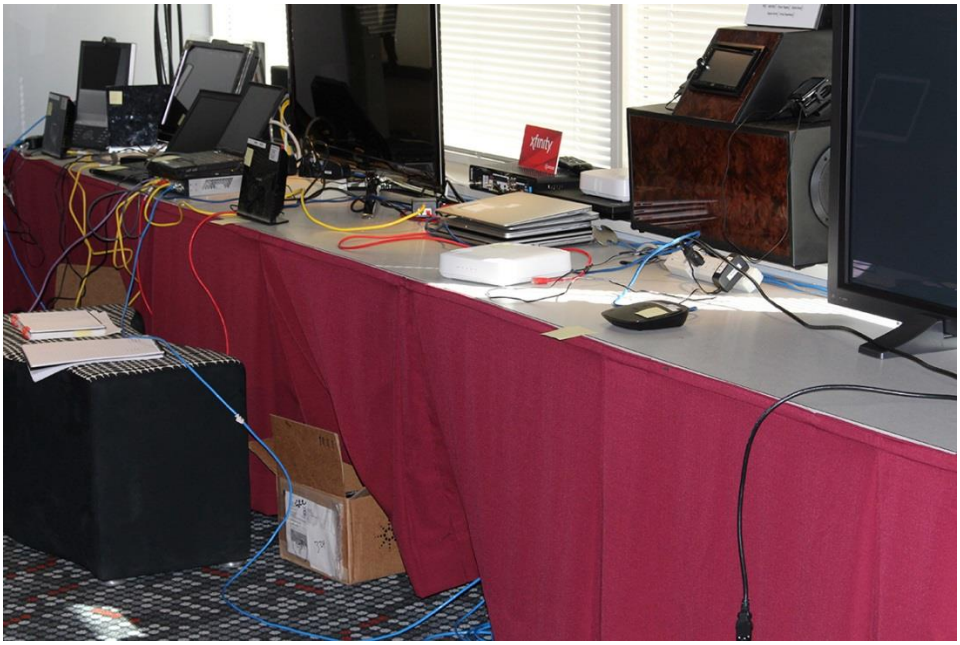
- Chs. 1, 6, and 11
- Chs. 1, 2x6, and 11
- Chs. 1, 6, 11, and 14

CableLabs' Demonstrations of TLPS Impact on Wi-Fi Devices

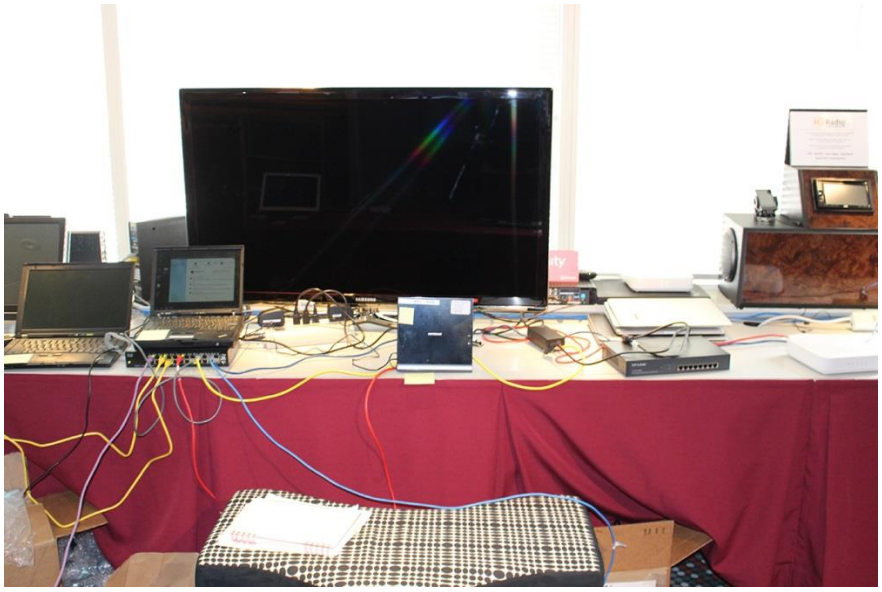
For CableLab's Wi-Fi demonstrations of the TLPS impact, on March 9-10, 2015, two Netgear R6200 APs set to operate on Wi-Fi channel 6, a Belkin N150 AP and Ruckus Wireless N700 AP both set to operate on Wi-Fi channel 11, and two Ruckus Wireless 7982 APs set to operate on channel 14, were spaced 5 feet apart on a table, and one Wi-Fi client device was placed 5 feet from each AP, as shown in the figure below. The APs were set to transmit at a maximum level of 20 dBm (100 mW) conducted power, 31 dBm (1250 mW) equivalent isotropically radiated power (EIRP).



Not to scale. For illustration purposes only.



Netgear and Ruckus Wireless APs



Netgear and Ruckus Wireless APs

IxChariot Wi-Fi data generators were connected to the APs to generate the Wi-Fi traffic (Spirent SMB-600 with 8 Gbyte Ethernet ports and 1 IxChariot server, with a Gigabit Ethernet switch and 802.11n Wi-Fi bridge). Blast (as much data as can be received) transmission control protocol (TCP) uplink and downlink transmissions were used to measure the throughput rate on Wi-Fi channel 11 for 3 minutes for the channel combinations listed below. Real-time transport protocol (RTP) uplink and downlink transmissions at 1.45 Mbps were used to measure the latency and jitter rates on channel 11 during two 1.5 minute demonstrations for the channel combinations listed below. Traffic on interfering networks was generated identically for RTP and TCP demonstrations. Baseline performance on channel 11 was measured in the absence of an AP operating on channel 14. Baseline performance on channel 11 was also measured in the absence of channel 6 operations.

Date	Simultaneous Channels Demonstrated	AP Devices Used	Client Devices Used
3/9/15	1 CH 6 + 1 CH 11 + 1 CH 14	CH6: Netgear R6200 CH 11: Belkin N150 CH 14: Ruckus 7982	CH 6: Dell Inspiron/Macbook Air CH 11: Samsung Galaxy S5 CH 14: Nexus 7 Tablet
3/10/15	2 CH 6 + 1 CH 11 + 2 CH 14	CH6: Netgear R6200 CH 11: Belkin N150 CH 14: Ruckus 7982	CH 6: Dell Inspiron/Macbook Air CH 11: Samsung Galaxy S5 CH 14: Nexus 7 Tablet
3/10/15	2 CH 6 + 1 CH 11 + 2 CH 14	CH6: Netgear R6200 CH 11: Ruckus N700 CH 14: Ruckus 7982	CH 6: Dell Inspiron/Macbook Air CH 11: Macbook Pro CH 14: Nexus 7 Tablet